

# A SMALL, INEXPENSIVE MOONBOUNCE ANTENNA SYSTEM FOR 144 MHz



AS - 49 - 15

DIVISION OF VARIAN

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## A SMALL INEXPENSIVE MOONBOUNCE ANTENNA SYSTEM FOR 144 MHZ

Effective performance with a small, lightweight antenna that can be built with hardware-store materials and yet performs when the most elaborate and expensive e.m.e. arrays don't!

The idea of DXing via the moon is at once enticing and frightening to many amateurs. Few amateur radio pursuits can match the challenge and the thrill of a completed moonbounce QSO, but the complexity and cost of an e.m.e. system frightens some hams.

Many amateurs think of moonbounce systems in terms of high power, costly receiving preamps, and antennas big enough to fill football fields.

Some e.m.e. systems are that elaborate, to be sure, but K6YNB/KL7 enjoyed considerable success during his 1976 moonbounce DXpedition with a very simple and inexpensive system, including an antenna small enough to be set up by one person in half a day.

The transmitter used a popular commercial transceiver driving a push-pull 4CX250B amplifier. The receiving front end employed low-cost preamps similar to the U310 design in this series. (1)

What was unique about the Alaskan moonbounce system was the antenna, a 19 foot by 19 foot array of 16 three-element cubical quads made from wood and #12 copper wire. The antenna mount used nothing more sophisticated than one Ham-M rotator and four small TV antenna rotors, but it was steerable in polarization as well as elevation and azimuth. It could easily be adapted to rotate in all three ways using ropes rather than rotors for steering, reducing the total cost of the antenna system, including phasing cables, well below \$100.

### CONQUERING FARADAY

The unique feature of the array, of course, is its steerability in polarization. As everyone who has read this far into the Moonbounce series knows, the biggest obstacle to reliable earth-moon-earth communication between properly equipped stations is "Faraday Rotation", with its ability to

shift the polarization of signals leaving and re-entering the earth's atmosphere.

Faraday Rotation often renders two well equipped stations unable to hear each other for extended periods of time, or may leave an operator hearing a station that cannot hear him.

On 432 MHz it is not unusual to solve this problem by using a dish antenna and rotating the feed to match the polarization of the incoming signal. On two meters, however, a dish big enough for e.m.e. work is beyond most amateurs' means. Circular polarization will also solve the problem, but the added gain required for e.m.e. work when the signal is omnipolarized again makes amateur-size arrays too small for moonbounce work on two meters.

There are two solutions to the Faraday problem at 144 MHz:

1) to wait until rotation changes, which may mean waiting hours for a completed two-way exchange; or 2) build an array that can be shifted in polarization to match that required for e.m.e. communication at the moment.

The K6YNB Alaskan array takes the latter approach, and does it simply. Obviously, polarization rotation is only possible when the individual antennas being rotated will clear the tower. Of course, even very long yagis can be supported from the rear so they may be rotated in polarization without hitting the supporting frame, but that presents another tough set of mechanical problems. K6YNB chose to use small lightweight antennas with very short (30 inch) booms to simplify the mechanical problems of shifting the polarization.

With these short-boom quads, the entire frame will rotate  $360^{\circ}$  on its axis to match any incoming polarization with the moon as low as  $5^{\circ}$  above the horizon.

#### THE THREE-WAY ROTATOR

As the accompanying photos illustrate, the array uses a CDE Ham-M rotor on a small tower to control azimuth. Atop the Ham-M are two Alliance T-45 TV rotors wired in parallel. These little rotors elevate a mast on which two more T-45s are mounted. These T-45 rotors turn the main axle on which the e.m.e. frame is mounted. As long as the booms of the 16 quads are mounted parallel to this central axle the whole thing will steer in azimuth, elevation and polarization simultaneously.



The method of paralleling Alliance rotors is described in Ham Radio magazine by Forrest Gehrke.<sup>(2)</sup> Suffice it to say here that the job involves making sure the rotors to be paralleled are in the same position (e.g. both fully clockwise) and then wiring the three motor terminals of rotor #2 to the same terminals of rotor #1. The indicator leads need not be paralleled.

To provide adequate voltage and current capability for two motors, remove the transformer and AC capacitor from one control box, mount them on the rear of the other, and carefully wire everything in parallel. Take care not to reverse the leads on the two transformers.

For those who do not wish to acquire five rotors, even when four of them sell for under \$35 apiece, there is an even less expensive way to go. Use ropes instead of the T-45s to steer both elevation and polarization. All you need to do this is some kind of homemade bearings for the rotating pipes.

#### ABOUT THE CUBICAL QUADS

Many amateurs feel that cubical quads do not work well, especially at VHF. Wherever this myth began, we would like to dispose of it now. As all recent literature on quads indicates, a three-element quad has perhaps 2 dB more gain than a three-element yagi. It takes a yagi with nearly a 5-foot boom to equal the gain of these quads with their 30-inch booms, as J. E. Lindsay pointed out in his definitive study of Quads vs. Yagis.<sup>(3)</sup> The quads used here have been measured at 9.1 dBd per bay, a little less than the theoretical figure of 9.3 dBd cited by William Orr in the second edition of his cubical quad handbook.<sup>(4)</sup>

Not only does the choice of quads make it possible to shift the polarization more easily, but it also reduces the cost and simplifies the impedance matching and phasing problems.

The quads are made of clear pine booms ( $3/4 \times 3/4$  molding is good for this) with even lighter molding for spreaders. #12 TW covered wire, normally used for AC house wiring, forms the elements. The director and reflector are cut to the dimensions shown, shaped in a square and soldered at the bottom to form a closed loop. The driven element has an SO-239 coaxial connector soldered directly to the two sides of the loop at the bottom. There is no matching or balancing of any kind! For a permanent non-portable installation, the connectors may be eliminated. Attach the ends of each driven element loop to a plexiglass insulator so the phasing lines may be soldered in place.



If the dimensions are followed, the only trick to achieving success with these antennas is to remember that all 16 must be fed with the center conductor in the same position relative to the others. You cannot feed some with the center conductor going to the right side of the driven element while others are fed to the left.

To avoid this mishap, build one quad and then set it aside as a reference antenna and build all the others exactly the same way.

When you mount the quads on the supporting frame, don't spoil everything by mounting some of them upside down or sideways in relation to the others!

#### THE SUPPORTING FRAME

The supporting frame consists of two 25 foot lengths of aluminum, tapering down from 1½" at the center, and mounted on the main axle (a length of standard TV mast material).

To prevent sag in any plane, the spreaders are connected with a square of rope, so that the assembly resembles one element of a twenty-meter cubical quad with its wire loop. Then the four spreaders are supported with additional outriggers up to the main axle, which extends four feet beyond the main hub for this purpose.

At a point 4'2" from the outer end of each spreader, there is an 8'4" cross spreader of 1" aluminum tubing on which two quads will be mounted. The other two quads on each of the four arms are mounted directly on the spreader itself.

There are many ways to attach these little quads to the spreaders. Any sort of lightweight bracket will do. CUSHCRAFT or KLM element-to-boom brackets work well.

#### THE PHASING HARNESS

Each quad has a characteristic impedance of about 60 ohms. A full electrical wavelength of lightweight RG-59 type coax reproduces that 60 ohms at a four-way junction, producing 15 ohms at one point on each spreader arm. Four 1.75 wavelength sections of RG-11 transform the 15 ohm up to about 375 ohms. The four RG-11 lines join at the center of the array, producing an impedance of about 93 ohms, which goes through a single quarter wavelength of RG-11 to produce an impedance around 54 ohms and a virtually flat SWR at resonance.

Here is a step-by-step procedure for making the phasing lines.

- 1) Buy 100 feet of Belden 8221 coax, a lightweight foam line similar to RG-59. If you use any other brand or type, the dimensions given here will probably have to be recalculated because velocity factors vary widely from the nominal published parameters.
- 2) Cut the 8221 into 16 six-foot lengths and mount a PL-259 connector with a UG-176 adaptor on one end of each. In a permanent installation, the cables may be soldered directly on the quads, avoiding the cost and losses in these connectors.
- 3) Now measure each 8221 line from the tip of the connector and cut each down to 5'7" (67"), including the length of the connector.
- 4) Strip back 5/8" of insulation on the open end and solder four 8221 cables to each of four S0-239s, attaching one braid to each mounting hole and bringing all four center conductors into the S0-239s center pin.
- 5) Now cut four 96" (8') lengths of Belden 8238 RG-11 coax. Mount a PL-259 on one end of each, then strip 5/8" from the other ends and mount all four on another S0-239 (or Type N) at the center.
- 6) Cut a 13½" length of RG-11, put connectors on both ends, and attach it from the center junction to the antenna relay.
- 7) Weatherproof all phasing lines thoroughly for permanent installations.

An antenna mounted relay and preamp are strongly recommended, although a short run of low-loss cable such as RG-17 may be used. This will keep the relay and preamp inside, away from the weather, sacrificing a little performance for reliability.

#### PUTTING IT UP

Assembling the array is pretty simple. Put the rotating mount on your supporting mast or tower. Make sure your array will steer without hitting trees, buildings, or other obstructions. Now assemble the spreaders and connect the supporting ropes.

Finally, mount the quads one at a time, rotating the array after mounting each so the thing doesn't become too imbalanced. A hint: this is easier if the main axle is free to spin. Connect the phasing lines and attach your feedline(s).

### HOW IT PERFORMS

After using a moonbounce array that is steerable only in elevation and azimuth, using this array is a revelation. Even though the system as described here is an exceptionally small and lightweight e.m.e. array with only about 20.2 dBd gain, it behaves as if it has much more, because you can always be sure the polarization is optimized. With an ordinary array, you often struggle to hear weak signals (or to be heard yourself) because the polarization is far from correct.

In two weeks of e.m.e. schedules at K6YNB/KL7 it was found that incoming signals were rarely exactly horizontal in polarization.

It was almost always necessary to move to a polarization other than "normal" for best signals. About half the time, the other station seemed to hear K6YNB/KL7 at the same polarization setting that produced the best received signal. On other occasions, various polarizations had to be tried until the other station began responding with "O"s.

Regardless of the Faraday situation at a given moment, however, it was always possible to acquire the signal of well-equipped e.m.e. stations within a few minutes, and most QSOs were completed within 15 or 20 minutes. If no signal was heard in that period of time, it was a pretty good indication that the two stations did not have enough system gain between them to overcome the path loss and make a contact for that day!

With this system, Faraday Rotation ceases to be a serious obstacle to e.m.e. communication.

### THE CONCLUSION

This is not the biggest moonbounce antenna around, but it may be one of the simplest and easiest to put together. And it clearly performs well enough to produce lots of good signals off the moon with a pair of 4CX250Bs at 1000 watts input.

At this writing, there are probably 30 stations around the world on two meters with enough system gain to work a station using this antenna consistently.



## REFERENCES

1. A Pre-Amplifier for 144 MHz EME - AS49-9
2. Gehrke, Forrest, "Antenna Rotator for Medium Sized Beams," Ham Radio, May 1976, page 48.
3. Lindsay, J.E., "Quads vs. Yagis", QST, May 1968, page 11.
4. Orr, William, All About Cubical Quad Antennas, 2nd ed., Wilton, Conn.: Radio Publications Inc., 1970.

DESIGN DATA - THREE ELEMENT CUBICAL QUAD FOR 144 MHz

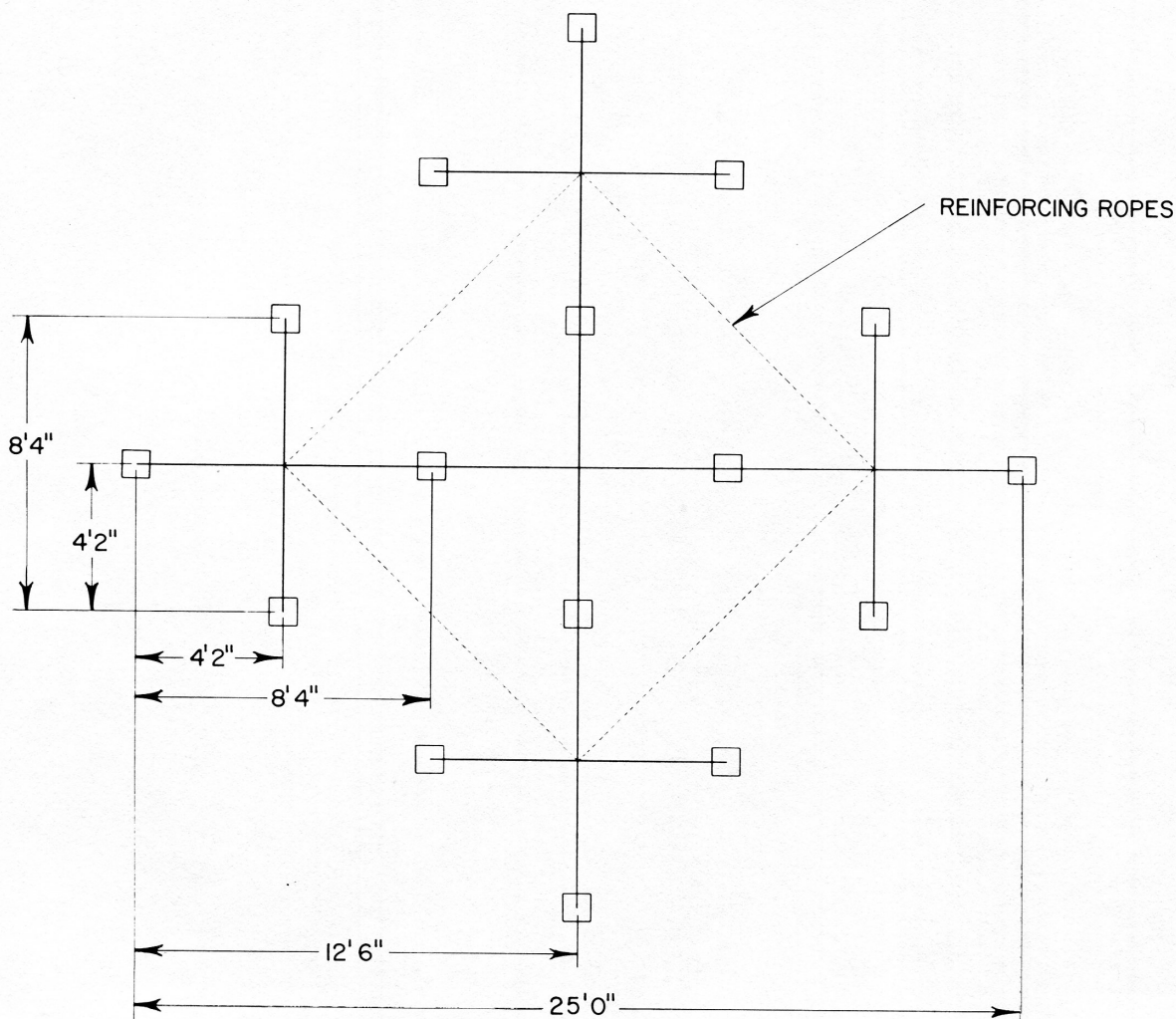
Reflector -  $86\frac{1}{2}$ " loop of #12 TW copper wire, covered, soldered closed at bottom.

Driven element - 82" loop of #12 wire, with coaxial connector mounted at bottom center.

Director - 77" loop of #12 wire, soldered closed at bottom.

Spacing: 18" Refl. to DE, 12" DE to Director.

Phasing Harness: 16 lengths of Belden 8221 cable, each 67" long, to four four-way junctions; 4 lengths of Belden 8238 (RG-11), each 96" long, from four-way junctions to center of array; single  $13\frac{1}{2}$ " length of RG-11 to feedpoint/relay.



PHYSICAL DESCRIPTION OF THE ARRAY

The array is made up of sixteen three element Quads.  
The Quads are spaced four feet two inches apart.  
The total size of the array is 19 feet by 19 feet square.  
The spreaders are 25 feet long.



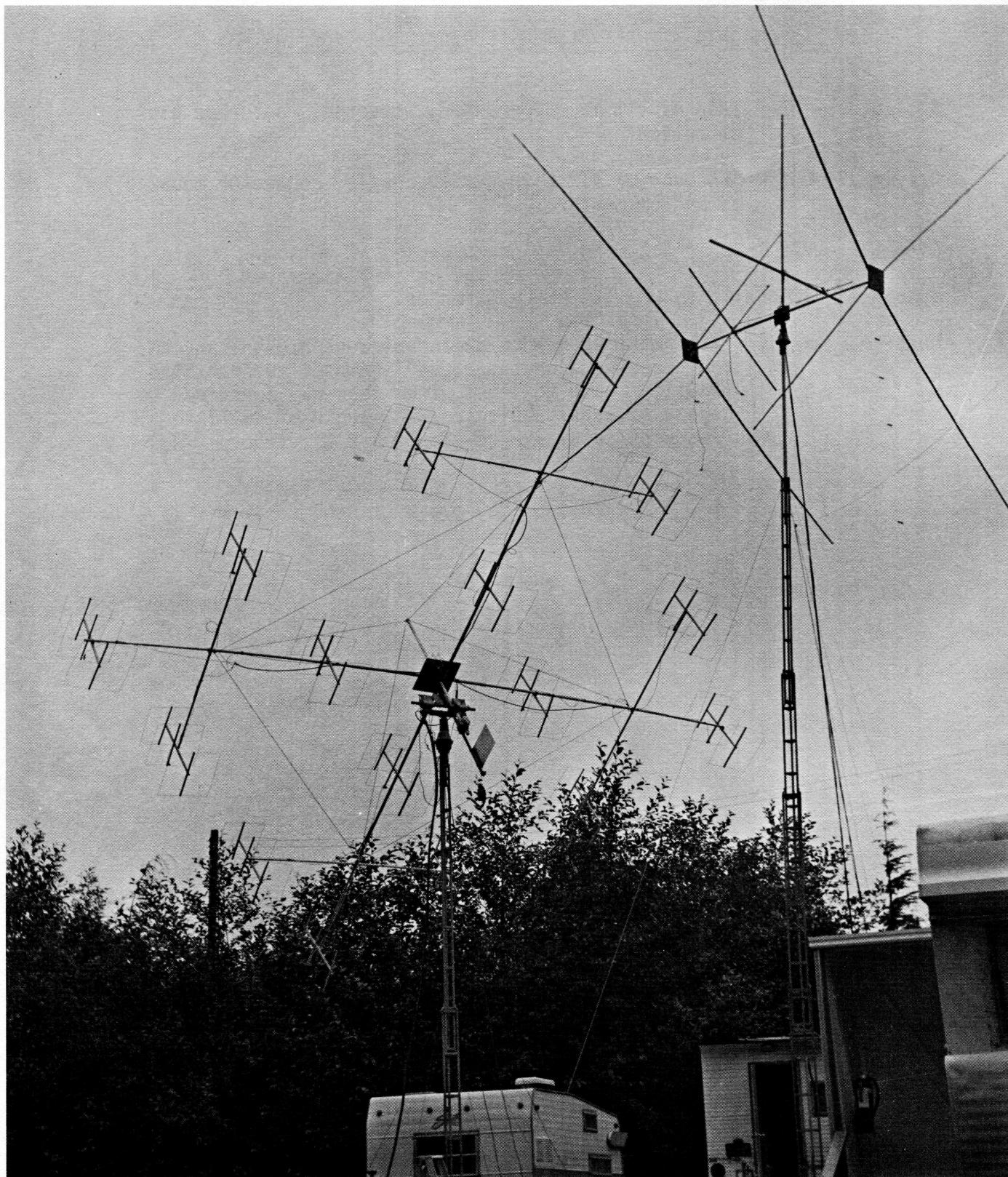


FIGURE 1

This is K6YNB's moonbounce station as it appeared in Ketchikan, Alaska. At left is the array of 16 three-element quads for 144 MHz with its three-way steerable mount. At right, on the tower mounted on the camper truck, is a two-element quad used for liaison communication on 20 meters. With this system, K6YNB/KL7 worked 15 states on two meters in two weeks, 13 of them via the moon!



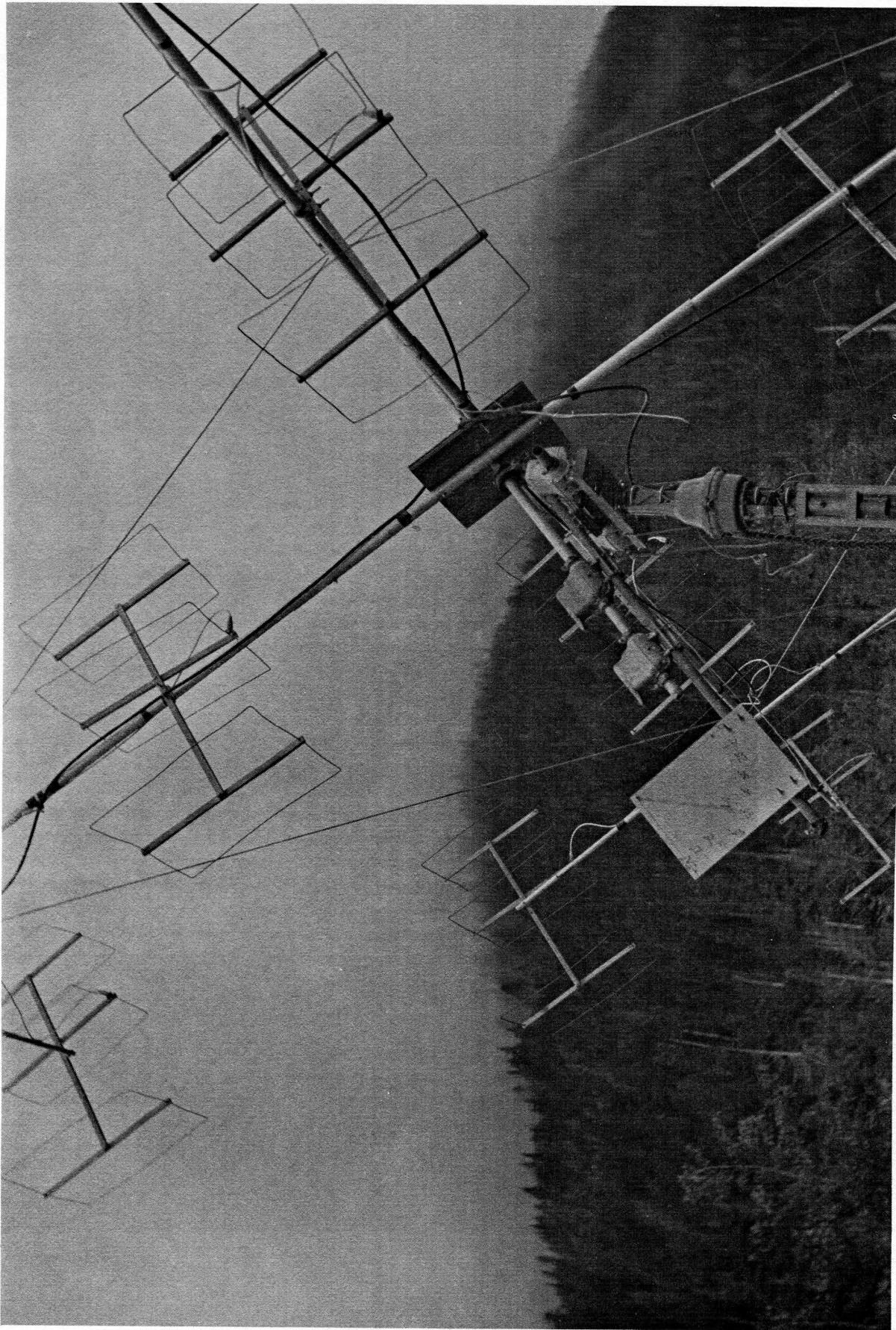


FIGURE 2

This shows the detail of the three-way mount, capable of steering the moonbounce array in azimuth (the Ham-M rotor on the tower), elevation (the two TV antenna rotors on the Ham-M), and polarization (the two TV rotors on the elevated pipe). A homemade tractor accurately reads the elevation, and a filter choke provides counterweight (recommended value: 10 Henry at 200 mAdc).



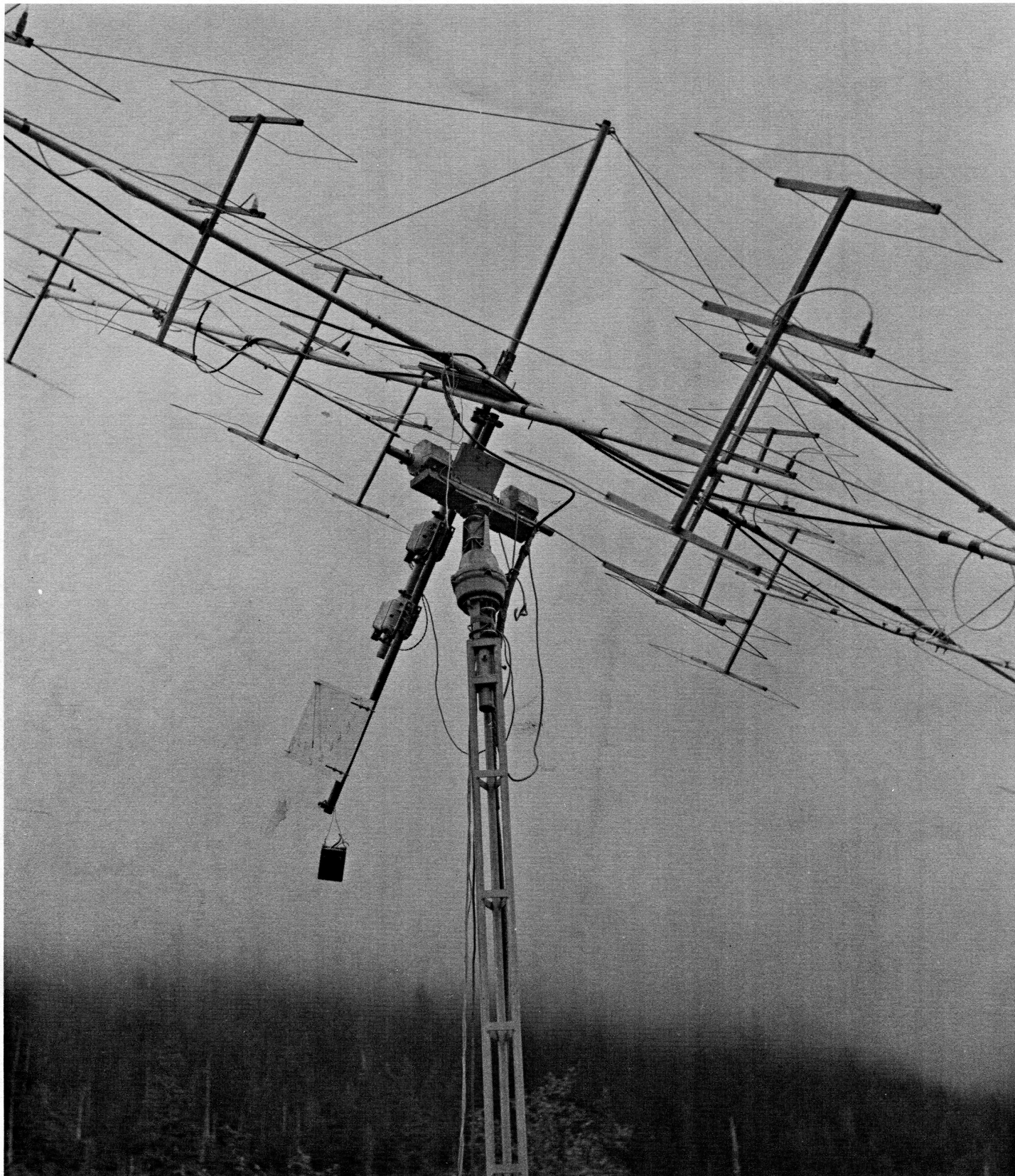


FIGURE 3

Here's another view of the e.m.e. array, against a backdrop of the perennial fog of Southeastern Alaska.